AD-A038 587 ARMY ARMAMENT COMMAND ROCK ISLAND ILL SYSTEMS ANALYS--ETC F/G 5/2

SYSTEMS ANALYSIS DIRECTORATE ACTIVITIES SUMMARY NOVEMBER 1976.(U)

DEC 76

UNCLASSIFIED DRSAR/SA/N-60 NL

1 OF 1

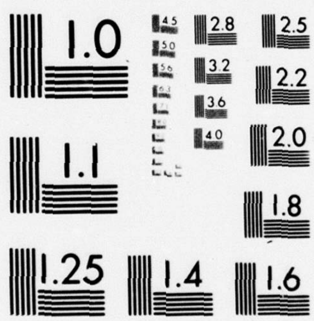
ADA038587

END

DATE

FILMED

5-77



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

12

2

B.S.

AD

DRSAR/SA/N-60

SYSTEMS ANALYSIS DIRECTORATE
ACTIVITIES SUMMARY
NOVEMBER 1976

DECEMBER 1976

Approved for public release; distribution unlimited.

US ARMY ARMAMENT COMMAND
SYSTEMS ANALYSIS DIRECTORATE
ROCK ISLAND, ILLINOIS 61201

DISPOSITION

Destroy this report when no longer needed. Do not return it to the originator.

DISCLAIMER

The findings in this report are not to be construed as an official Department of the Army position.

WARNING

Information and data contained in this document are based on input available at the time of preparation. Because the results may be subject to change, this document should not be construed to represent the official position of the US Army Development & Readiness Command unless so stated.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER
14 DRSAR/SA/N-60

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
6 SYSTEMS ANALYSIS DIRECTORATE ACTIVITIES SUMMARY NOVEMBER 1976.

5. TYPE OF REPORT & PERIOD COVERED
9 Note - Final rept.

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)

8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS
US Army Armament Command
Systems Analysis Directorate (DRSAR-SA)
Rock Island, IL 61201

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

11. CONTROLLING OFFICE NAME AND ADDRESS
US Army Armament Command
Systems Analysis Directorate (DRSAR-SA)
Rock Island, IL 61201

12. REPORT DATE
11 Dec[redacted]76

13. NUMBER OF PAGES
63 12 46p.

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)

15. SECURITY CLASS. (of this report)
UNCLASSIFIED

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Protective Mask, XM29
Navy 5", 155mm Sleeved Round
Copperhead
Footprint
HELLFIRE
Laser Designator
[redacted]

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This monthly publication contains Memoranda for Record and other technical information that summarize the activities of the Systems Analysis Directorate, US Army Armament Command, Rock Island, IL.

The subjects dealt with are: Protective Mask, XM29; Footprints of Army and Navy Guided Projectiles; Copperhead and HELLFIRE, [redacted]

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

409517

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

CONTENTS

Next page is blank.

Section I. GENERAL

1. This monthly publication summarizes the activities of the Systems Analysis Directorate. The purpose of this note is to give wider and more timely distribution on subjects of concern to the command.

2. The most significant Memoranda for Record (MFR's) and other technical information will be published as notes or reports at a later date.

3. In order to assure accurate distribution of this publication, addition or deletion of addresses to/from the DISTRIBUTION LIST are invited and should be forwarded to the address below.

4. Inquiries applicable to specific items of interest may be forwarded to Commander, US Army Armament Command, ATTN: DRSAR-SA, Rock Island, IL 61201 (AUTOVON 793-4483/4628).

Next page is blank.

Section II. MEMORANDA AND OTHER TECHNICAL INFORMATION

Memoranda for Record and other technical information are grouped according to subject, where applicable, and in chronological order.

Next page is blank.

ADDENDA TO COMPARISON OF FOOTPRINTS OF ARMY AND NAVY GUIDED PROJECTILES

Next page is blank.

DRSAR-SAM 11 NOV

MEMORANDUM FOR RECORD

SUBJECT: Addenda to Comparison of Footprints of Army and Navy Guided Projectiles

1. References:

a. Memorandum for Record, DRSAR-SAM, 16 Jul 76, subject: Computer Simulation Study of Navy 5"/155mm Sleeved Round for Guidance Accuracy and Footprint.

b. Memorandum for Record, DRSAR-SAM, 31 Aug 76, subject: Computer Simulation Study of Copperhead (CLGP) for Guidance Accuracy and Footprint.

c. Briefing for DDR&E by George Schlenker and Richard Heider, 14 Sep 76, subject: Inputs to Army-Navy Guided Projectile Commonality Study.

2. Introduction.

At the referenced briefing (Ref 1c), the undersigned presented inputs to and results from the studies of Refs 1a and 1b to an audience of Army, Navy, and DOD personnel.

The Navy personnel present took issue with the value of the seeker field of view (FOV) used by DRSAR-SA for the Navy round. Discussion established that the value furnished SA in the Navy's system specification of March 1976 had been superseded in May 1976 without SA having been notified.

In order to assure that the performance estimates of the Navy projectile were not unfairly pessimistic, the undersigned agreed to repeat the experiments on the Navy footprint, using the newer value of $\pm 17^{\circ}$ instead

of the older $\pm$ 12° for the FOV.

3. Experimental Results.

The footprint experiments were performed in the manner described in previous studies (see Ref 1a), but with a larger number of experimental points to better define the footprints.

Results of the present experiment, including, for the first time, ceilings above 3000 ft, are displayed in Figures 1-3 and Table 1.

4. Comments

a. Comparison of the present results with the previous ones (Ref 1a) reveals the following:

(1) At 6 km gun-to-target range (GTR), the sizes of the footprints increase significantly. However, the utility of the footprints is essentially unchanged. See comments on these footprints in Refs 1a and 1b.

(2) At 12 km GTR the increases in size result in increased utility.

(3) At 18 km GTR the differences in sizes are entirely attributable to the increased precision of the present experiment. No increase is attributable to the increased FOV. Indeed, the output of the computer simulation reveals that, for 18 km GTR and ceiling $\leq$ 3000 ft, the boundary of the footprint is everywhere determined by maneuverability, not ability to see and acquire the target.

b. Substitution of the new values for the old does not change the

DRSAR-SAM

MEMORANDUM FOR RECORD

SUBJECT: Addenda to Comparison of Footprints of Army and Navy Guided Projectiles

conclusions of Ref 1a in regard to selection of ignition delay option, nor does it change the conclusions of Ref 1b in regard to comparison of Copperhead vis-a-vis the Navy projectile.

Richard D. Heider

RICHARD D. HEIDER
Operations Research Analyst
Methodology Division
Systems Analysis Directorate

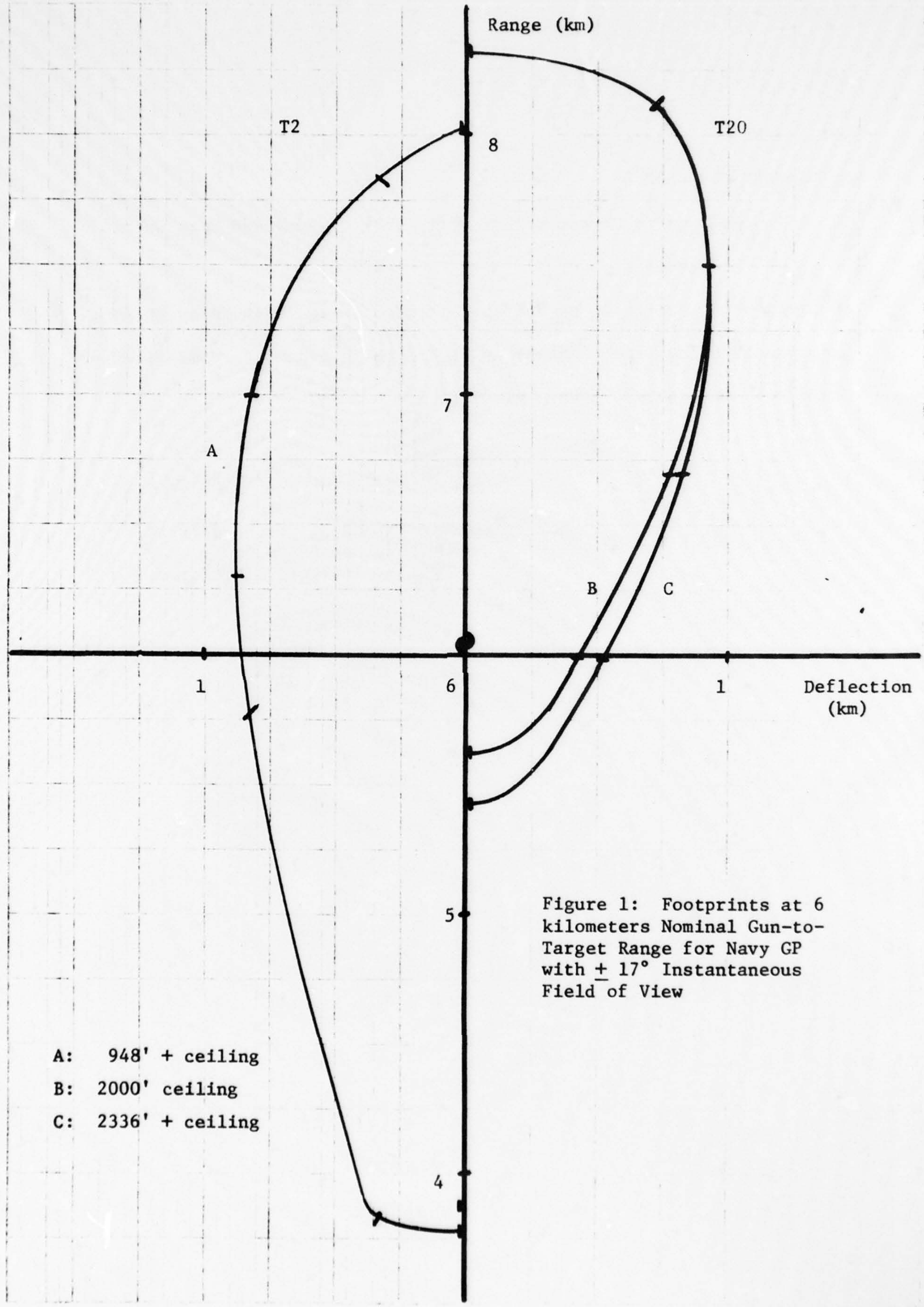
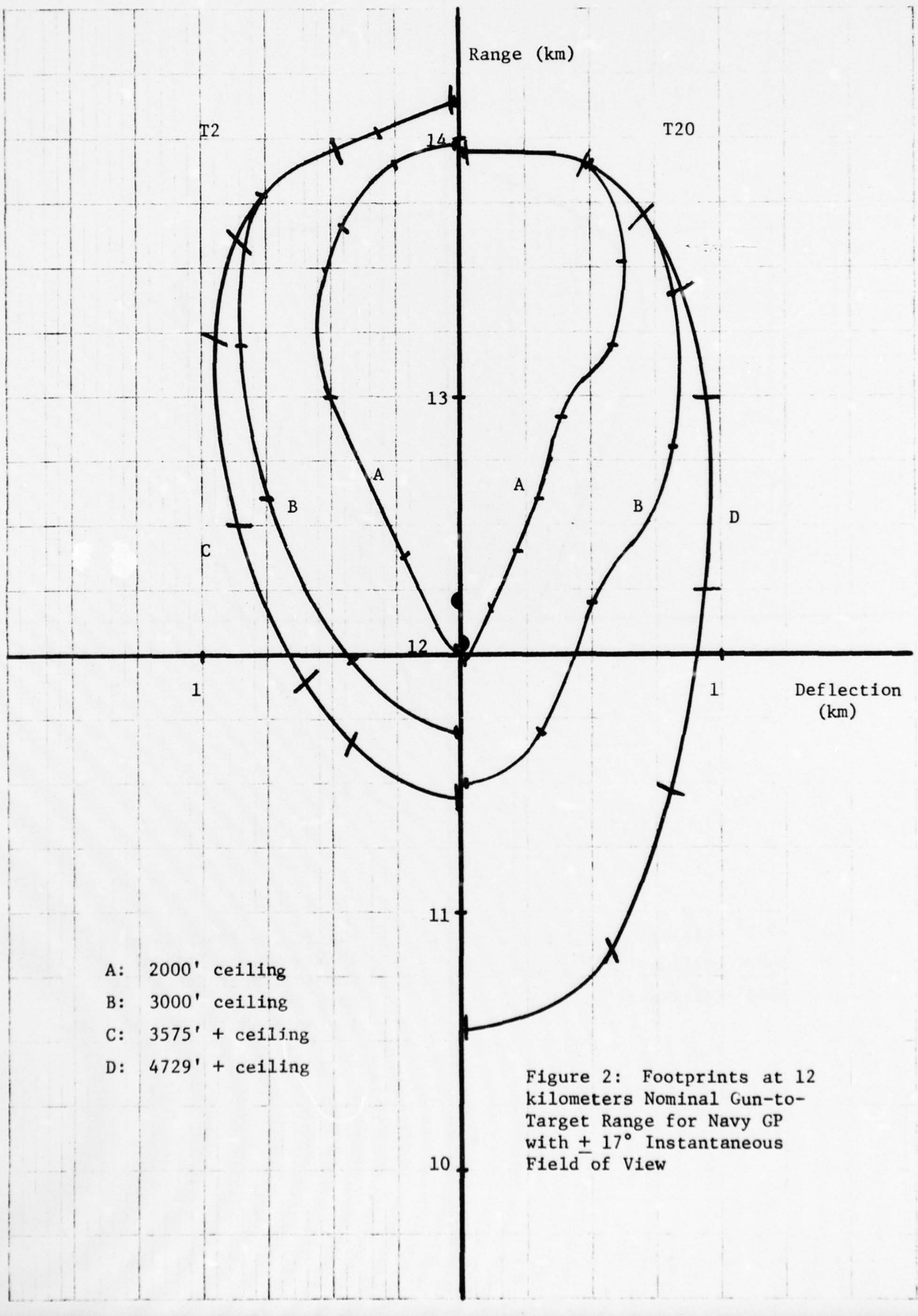


Figure 1: Footprints at 6 kilometers Nominal Gun-to-Target Range for Navy GP with ± 17° Instantaneous Field of View



A: 2000' ceiling

B: 3000' ceiling

C: 3575' + ceiling

D: 4729' + ceiling

Figure 2: Footprints at 12 kilometers Nominal Gun-to-Target Range for Navy GP with $\pm$ 17° Instantaneous Field of View

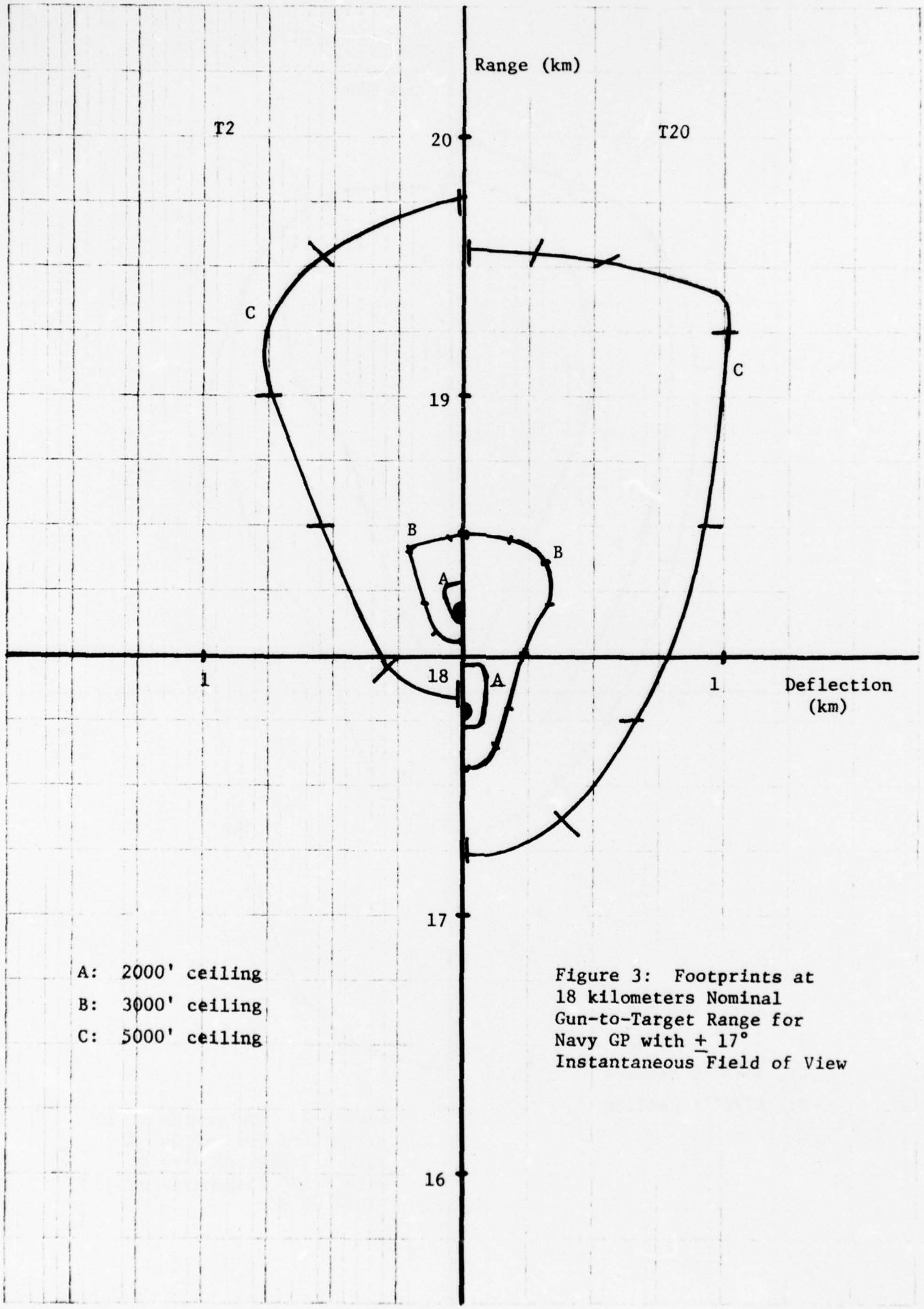


Figure 3: Footprints at 18 kilometers Nominal Gun-to-Target Range for Navy GP with $\pm$ 17° Instantaneous Field of View

TABLE 1: Footprint Areas for Navy GP with $\pm$ 17° FOV

Ceiling (ft)	6 km		12 km		18 km	
	T2	T20	T2	T20	T2	T20
948+	5.73	----	----	----	----	----
2000	5.73	3.81	1.46	1.54	0.01	0.04
2336+	5.73	4.13	----	----	----	----
3000	5.73	4.13	3.05	3.12	0.13	0.41
3575+	5.73	4.13	3.95	----	----	----
4729+	5.73	4.13	3.95	5.42	----	----
5000	5.73	4.13	3.95	5.42	2.15	3.70

Next page is blank.

DRAFT INDEPENDENT EVALUATION PLAN (IEP)

FOR DT I OF THE NEW PROTECTIVE MASK

Next page is blank.

DRSAR-SA (2 Nov 76) 1st Ind
SUBJECT: Draft Independent Evaluation Plan (IEP) for DT I of the New Protective Mask

HQ, US Army Armament Command, Rock Island, IL 61201 12 NOV 1976

TO: Commander, US Army Test and Evaluation Command, ATTN: DRSTE-SY, Aberdeen Proving Ground, MD 21005

DRSAR-SA has reviewed the subject draft IEP as requested. Our specific comments are provided as Incl 2 on DA Form 2028.

FOR THE COMMANDER:

Morris C. Johnson

MORRIS C. JOHNSON
Acting Director
Systems Analysis Directorate

1 Incl
wd incl 1
Added 1 incl
2. DA 2028

Next page is blank.

DEPARTMENT OF THE ARMY
HEADQUARTERS, U. S. ARMY TEST AND EVALUATION COMMAND
ABERDEEN PROVING GROUND, MARYLAND 21005

Mr. Ritondo/nr/AU 283-5279

S-15 Nov 76

DRSTE-SY

2 NOV 1976

SUBJECT: Draft Independent Evaluation Plan (IEP) for DT I of the New Protective Mask

Commander
US Army Armament Command
ATTN: DRSAR-SA (Mr. O. Haase)
Rock Island Arsenal, IL

1. Due to the tight schedule dictated by the accelerated schedule for development of the New Protective Mask, an abbreviated IEP has been drafted.

2. The attached DRAFT IEP for DT I of the New Protective Mask is forwarded for coordination with the ARMCOM Red Team. Your concurrence and/or comments are requested NLT 15 November 1976.

3. For additional information and/or questions relating to the IEP, contact Mr. Michael C. Ritondo, SAED, AUTOVON 283-5279/5280.

FOR THE COMMANDER:

1 Incl
as

RICHARD H. RIEL
Director
Sys Anal & Eval Directorate

CF:
Cdr, Edgewood Arsenal, ATTN: SAREA-DE-DPR (Mr. C. Shoemaker), Aberdeen Proving Ground, MD 21010

AMERICAN REVOLUTION BICENTENNIAL 1776-1976

INCL 2

RECOMMENDED CHANGES TO PUBLICATIONS AND BLANK FORMS

For use of this form, see AR 310-1; the proponent agency is the US Army Adjutant General Center.

Use Part II (reverse) for Repair Parts and Special Tool Lists (RPSTL) and Supply Catalogs/Supply Manuals (SC/SM).

DATE

TO: (Forward to proponent of publication or form) (Include ZIP Code)
Commander
US Army Test & Evaluation Command
ATTN: DRSTE-SY
Aberdeen Proving Ground, MD 21005

FROM: (Activity and location) (Include ZIP Code)
Commander
US Army Armament Command
ATTN: DRSAR-SAM
Rock Island, IL 61201

PART I - ALL PUBLICATIONS (EXCEPT RPSTL AND SC/SM) AND BLANK FORMS

PUBLICATION/FORM NUMBER: Draft IEP

DATE: 2 Nov 76

TITLE: DT I Independent Evaluation Plan for XM29 Protective Mask

ITEM NO.	PAGE NO.	PARA-GRAPH	LINE NO.*	FIGURE NO.	TABLE NO.	RECOMMENDED CHANGES AND REASON (Exact wording of recommended change must be given)
1	2	B				COMMENT: This paragraph, as it exists, describes neither the threat nor the operational environment. It should be modified such that estimates of the expected dosage charge to masks can be made. Thus, it ties in with para E.1. on page 3.
2	3	E.1.				COMMENT: The dosage level of 2×10^4 mg-min/m^3 seems to be excessive for any single massive attack. This dosage level should be reviewed with the thought of reducing it to a more realistic value.
3	3	E.8.				CHANGE: The order of this subparagraph should be itemized among the critical issues. REASON: Paragraph B, page 2, points out that individuals may be required to assume CB protective postures for extended periods of time. Their ability to function in accomplishing their missions, while protected, is critical.
4	4	E.11.				COMMENT: Must be modified to include some reasonable estimate of likely or maximum storage times. REASON: Recent unfortunate experience with the seal of the M17 mask after storage should form the basis for "lessons learned" with respect to degradation of chemical protective equipment in storage. Storage times should be related to specific types of problems which might accrue while the mask is in storage.
5	4	E.14.				COMMENT: At least one other issue should be identified here: It has been noted that improperly fitted masks lead to leakages which can defeat the mask. Those improper fits can result from beards, dirt, and mismatches between mask sizes and individual head sizes. Proper

*Reference to line numbers within the paragraph or subparagraph.

TYPED NAME, GRADE OR TITLE: OTTO F. HAASE, JR. DRSAR-SAM

TELEPHONE EXCHANGE/AUTOVON, PLUS EXTENSION: ATV 793-3177

SIGNATURE

DA FORM 1 FEB 74 2028 — REPLACES DA FORM 2028, 1 DEC 68, WHICH WILL BE USED.

Incl 2

RECOMMENDED CHANGES TO PUBLICATIONS AND BLANK FORMS

For use of this form, see AR 310-1; the proponent agency is the US Army Adjutant General Center.

Use Part II *(reverse)* for Repair Parts and Special Tool Lists (RPSTL) and Supply Catalogs/Supply Manuals (SC/SM).

DATE

TO: *(Forward to proponent of publication or form) (Include ZIP Code)*
Commander
US Army Test & Evaluation Command
ATTN: DRSTE-SY
Aberdeen Proving Ground, MD 21005

FROM: *(Activity and location) (Include ZIP Code)*
Commander
US Army Armament Command
ATTN: DRSAR-SAM
Rock Island, IL 61201

PART I - ALL PUBLICATIONS (EXCEPT RPSTL AND SC/SM) AND BLANK FORMS

PUBLICATION/FORM NUMBER	DATE	TITLE
Draft IEP	2 Nov 76	DT I Independent Evaluation Plan for XM29 Protective Mask

ITEM NO.	PAGE NO.	PARA-GRAPH	LINE NO.*	FIGURE NO.	TABLE NO.	RECOMMENDED CHANGES AND REASON *(Exact wording of recommended change must be given)*
						consideration of these factors in a test program could lead to corrective measures which would preclude casualties resulting from mask leakage.
6	3	E.7.				CHANGE: Delete subparagraph E.7. REASON: The issue defined here is also defined under subparagraph D.4.
7	4					COMMENT: Perhaps the question of compatibility of the mask with other military equipment should be identified as a critical issue and added to this subparagraph. Although equipment such as binoculars, crew serve weapons, etc. have been identified in the critical issues section, the matter of compatibility with individual weapons such as side arms, rifles, rocket launchers, communication gear, etc. have not been given adequate attention. Likewise, the compatibility of the mask with armor, aircraft, shelters, etc. has not been explored to the fullest extent possible.
8	4	F				COMMENT: The statement is made here, without equivocation, that there are no known alternatives to the new protective masks. Surely the old protective masks, or product-improved versions of those old masks, should be considered alternatives.
9	4	A				COMMENT: A methodology for evaluation of the storability of the masks will be required in order to determine the techniques for evaluation. Some indication of the likely failure modes and the consequences would be desirable.
10	6	E.15.				COMMENT: Consistent with item 5 on page 1 of this review and item E.15. should be added here.

*Reference to line numbers within the paragraph or subparagraph.

TYPED NAME, GRADE OR TITLE	TELEPHONE EXCHANGE/AUTOVON, PLUS EXTENSION	SIGNATURE
OTTO F. HAASE, JR. DRSAR-SAM	ATV 793-3177	

DA FORM 1 FEB 74 2028 REPLACES DA FORM 2028, 1 DEC 68, WHICH WILL BE USED.

RECOMMENDED CHANGES TO PUBLICATIONS AND BLANK FORMS

For use of this form, see AR 310-1; the proponent agency is the US Army Adjutant General Center.

Use Part II (reverse) for Repair Parts and Special Tool Lists (RPSTL) and Supply Catalogs/Supply Manuals (SC/SM).

DATE

TO: (Forward to proponent of publication or form) (Include ZIP Code)
Commander
US Army Test & Evaluation Command
ATTN: DRSTE-SY
Aberdeen Proving Ground, MD 21005

FROM: (Activity and location) (Include ZIP Code)
Commander
US Army Armament Command
ATTN: DRSAR-SAM
Rock Island, IL

PART I - ALL PUBLICATIONS (EXCEPT RPSTL AND SC/SM) AND BLANK FORMS

PUBLICATION/FORM NUMBER	DATE	TITLE
Draft IEP	2 Nov 76	DT I Independent Evaluation Plan for XM29 Protective Mask

ITEM NO.	PAGE NO.	PARA-GRAPH	LINE NO.*	FIGURE NO.	TABLE NO.	RECOMMENDED CHANGES AND REASON (Exact wording of recommended change must be given)
						Data requirements for information related to mask leakage problems exists.

*Reference to line numbers within the paragraph or subparagraph.

TYPED NAME, GRADE OR TITLE	TELEPHONE EXCHANGE/AUTOVON, PLUS EXTENSION	SIGNATURE
OTTO F. HAASE, JR. DRSAR-SAM	ATV 793-3177	

DA FORM 1 FEB 74 2028 REPLACES DA FORM 2028, 1 DEC 68, WHICH WILL BE USED.

MAXIMUM FEASIBLE (CRITICAL) DESIGNATION

RANGE FOR COPPERHEAD AS A FUNCTION

OF SEVERAL PARAMETERS

Next page is blank.

DEPARTMENT OF THE ARMY
HEADQUARTERS, UNITED STATES ARMY ARMAMENT COMMAND
ROCK ISLAND, ILLINOIS 61201

REPLY TO ATTENTION OF:

DRSAR-SA

1 8 NOV 1976

SUBJECT: Maximum Feasible (Critical) Designation Range For Copperhead as a Function of Several Parameters

Commander
Picatinny Arsenal
ATTN: DRCPM-CAWS (Messrs. E. Manley & E. Zimpo)
Dover, NJ 07801

1. References:

a. Meeting at MICOM with G&C Lab Personnel, 14 Oct 76, subject: Laser Designator Characteristics and Implications for Terminal Guidance.

b. Memorandum for Record, AMSAR-SAM, 7 Jan 76, subject: The Problem of Laser Pulses from the Surroundings During Target Tracking and Designation (Spillover).

c. Memorandum for Record, DRSAR-SAM, 11 Nov 76, subject: Proportion of Energy Spilled Over a Target During Tracking With a Laser Designator and Implications for Terminal Guidance.

2. During discussions at the referenced meeting (Ref 1a), plans were made to investigate the guidance accuracy of HELLFIRE and Copperhead when used with several different laser designators. The intent of the planned investigation is to provide an estimate of the maximum range, for each designator, for which the flight vehicles satisfy their guidance accuracy requirements.

3. Reference 1b treats this subject analytically, in a simplified manner, under the assumption that the maximum feasible designation range is determined by the occurrence of laser pulses from the background created by spillover. However, Ref 1b did not explicitly treat certain parameters of interest and assumed that the energy density across the laser beam was uniform.

4. In an effort to guide the selection of parameter values for more detailed (and costly) simulation-based studies, DRSAR-SA has elaborated the approach taken in Ref 1b. A memorandum of the updated study (Ref 1c)

DRSAR-SA 1 2 NOV 1976
SUBJECT: Maximum Feasible (Critical) Designation Range For Copperhead as a Function of Several Parameters

is attached as Incl 1. In Ref 1c, the beam is given a gaussian energy profile and the Copperhead signal processing parameters associated with the target selection logic are treated explicitly. Additional parameters associated with the geometry of the scenario are also treated explicitly. Reference 1c also contains an expanded range of values of the parameters treated in Ref 1b.

5. Results in Ref 1c are provided for your information to update and supplement the preceeding information provided in Ref 1b.

FOR THE COMMANDER:

M. Khian

1 Incl
as

M. KHIAN
Acting Director
Systems Analysis Directorate

CF:
Cdr, Picatinny Arsenal, ATTN: DRCPM-CAWS/Mr. B. Barrett, Dover, NJ 07801
Cdr, USAVSCOM, P.O. Box 209, ATTN: DRSAV-WR/Mr. D. Dunlap, St. Louis, MO 63108
Cdr, USAMICOM, Attn: DRSMI-RCT/Mr. C. Lewis, Huntsville, AL 35809
Project Manager, Cannon Artillery Weapons Systems, Redstone Arsenal,
ATTN: DRCPM-CAWS-FO/COL Nulk, Huntsville, AL 35809

DRSAR-SAM

: : NOV 1976

MEMORANDUM FOR RECORD

SUBJECT: Proportion of Energy Spilled Over a Target During Tracking With a Laser Designator and Implications for Terminal Guidance

1. References:

a. Letter, DRSAR-SAM, 18 Jul 76, subject: Request Review of Document--Performance Requirements Tradeoff for Army Laser Designator Developments in Support of HELLFIRE and CLGP.

b. MFR, DRSAR-SAM, 17 Sep 76, subject: Review of the Response to GAO Information Request (No. 951283) Submitted by the HELLFIRE Project Office (HFPO).

c. MFR, AMSAR-SAM, 7 Jan 76, subject: The Problem of Laser Pulses from the Surroundings During Target Tracking and Designation (Spillover).

2. This memorandum is motivated in part by prior inquiries from the GAO and others into the relationship between laser designator characteristics and the guidance accuracy obtainable with associated laser guided systems such as Copperhead (CLGP) and HELLFIRE. This office has reviewed and supplemented information given the GAO by the HFPO on this subject (Refs 1a and 1b). Further motivation for this MFR is due to discussions held at MICOM on 14 Oct 76 relative to the above subject.

3. One can somewhat simplify the issue of guidance accuracy versus designator characteristics by restricting attention to assessing that range beyond which guidance accuracy fails to meet specified projectile performance requirements and/or beyond which there is a marked degradation of hit probability with additional designation range. In prior treatments of this subject such as Ref 1c, we have called this limiting range the maximum feasible (or critical) designation range. To determine the critical designation range with a given type of designator one must consider, inter alia, the question as to what is the maximum admissible amount of laser energy which is spilled over onto the background beyond the intended target per pulse. This limiting amount of spillover and the frequency with which it occurs is, of course, dependent upon a number of environmental (scenario-dependent) and projectile-dependent parameters. These are addressed in a simplified analytic treatment in Ref 1c.

4. In the following discussion additional attention will be given the distribution of laser energy over the beam cross section. (The energy

Incl 1

density was taken as uniform in Ref 1c.) Further attention will be given the seeker processor logic for discriminating the target from the background, given spillover. In particular, the implementation of last-significant-pulse logic in Copperhead will be treated. Following Ref 1c, a simplified treatment of the target geometry will be used to estimate the frequency with which the seeker would track the background during terminal guidance. Background pulses which are tracked will be referred to as "significant."

5. Approximate Distribution of Energy in the Far-Field Beam Cross Section.

Altho macroscopic spacial variations in the atmospheric index of refraction (10^{-4}-10m) along the optical path of the laser produce stochastic variation in the distribution of energy across the beam at the target (as well as beam broadening and beam steering effects), the temporal mean distribution of energy across the beam in the far field is approximately gaussian (normal). In the analysis here the beam energy distribution is taken as circular normal. Consider the beam section shown in Figure 1. The radius of the beam, r_b, is defined as that value of r at which the inclosed circle contains 90% of the total energy.

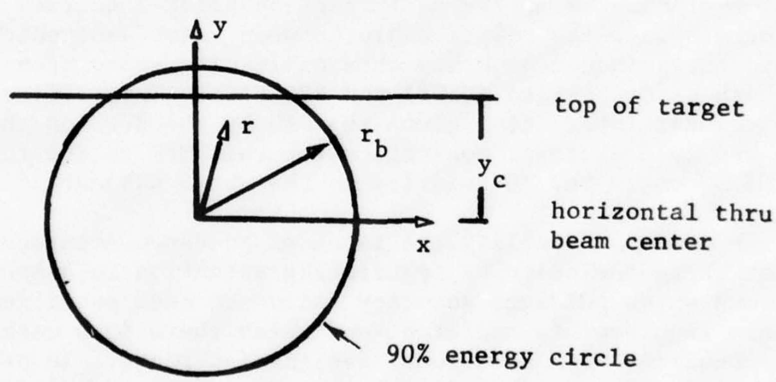


Figure 1. Beam Cross Section.

6. Let E represent the energy within a circle of radius r. Then, by assumption,

$$E = E_o\ (1 - \exp - \tfrac{1}{2}\ r^2/\sigma_b^2), \qquad (1)$$

with total beam energy/pulse E_o and with

$$\sigma_b = r_b/\sqrt{-2\ \ell n(0.1)} \tag{2}$$

so that $E(r_b) = 0.9$.

From (1)

$$\frac{dE}{dr} = \frac{E_o}{\sigma_b^2}\, r\, e^{-1/2(r/\sigma_b)^2} \quad . \tag{3}$$

7. Alternatively, the energy density with respect to each orthogonal coordinate is gaussian. For example,

$$d(E/E_o)/dy = \frac{1}{\sqrt{2\pi}\,\sigma_b}\ e^{-1/2(y/\sigma_b)^2} \ . \tag{4}$$

Suppose that the vertical dimension of the target is critical, ie, much smaller than the horizontal extent of the target relative to the center of aim. We shall be concerned about the fraction of the total energy in the beam below the level y_c in Figure 1. This fraction, f, is obtained by integration of the density, given by (4).

$$f = \frac{1}{\sqrt{2\pi}\,\sigma_b}\int_{-\infty}^{y_c} e^{-1/2(y/\sigma_b)^2}\, dy$$

$$f = \Phi\ (y_c/\sigma_b) \quad \text{, where } \Phi \text{ is the standard normal integral.} \tag{5}$$

As an approximation for Φ for $y_c/\sigma_b > 0$,

$$f = 0.5 + 0.5\ [1\text{-}\exp(-\ \tfrac{2}{\pi}(y_c/\sigma_b)^2)]^{1/2} \ , \tag{6}$$

where the maximum error in this approximation over the interval-- $0 < y_c/\sigma_b < \infty$ -- is less than about 0.003.

8. From (2) and (6),

$$f = 0.5 + 0.5[1\text{-}\exp(-2.9317\ y_c^2/r_b^2)]^{1/2} \ , \tag{7}$$

$y_c > 0$.

Thus, f is the fraction of the incident energy which falls on the target when the beam center is at a position y_c below the top edge of the target. To obtain the relative energy which is reflected from target and background one must take note of the reflectance of target and background. Notationally, let ρ_t represent the reflectance of the target and ρ_b that of the background. Then, the ratio of reflected energies--background to target--is

$$\rho_b(1-f)/(\rho_t f) \quad .$$

The energy from the background will travel a greater distance to reach the seeker than the energy from the target. In calculating the relative irradiance of the seeker dome contributed by these two sources, one must account for these different propagation paths. Thus, a relative attenuation of the background and target energies will be proportional to the square of the ratio of slant range from seeker to target, R_t, and from seeker to background, R_b. For the present purpose, effects due to differences in atmospheric extinction are ignored. An expression for R_b in terms of parameters of the engagement geometry is developed below. Notationally, let

$$\gamma = (R_t/R_b)^2 \quad , \tag{8}$$

and

$$\rho = \rho_b/\rho_t \quad . \tag{9}$$

Then, the ratio of the irradiance signals produced by background and target is

$$E_b/E_t = \gamma\rho(1-f)/f \quad , \tag{10a}$$

and, from (7),

$$E_b/E_t = \frac{\gamma\rho\{0.5-0.5[1-\exp(-2.9317\ y_c^2/r_b^2)]^{1/2}\}}{0.5+0.5[1-\exp(-2.9317\ y_c^2/r_b^2)]^{1/2}} \quad . \tag{10b}$$

1 1 NOV 1976

DRSAR-SAM

SUBJECT: Proportion of Energy Spilled Over a Target During Tracking With a Laser Designator and Implications for Terminal Guidance

9. Target Selection Algorithm.

In processing the laser pulses reflected from target and background the seeker of a laser guided projectile implicitly uses a critical or threshold value for the ratio E_b/E_t to select a target to track. For values of E_b/E_t greater than this value the background will be tracked. Otherwise, the intended target will be tracked. To see how this happens, consider the situation shown in Figures 2a and b. The reflected energy at the seeker is depicted in Figure 2c. In Figure 2a the origin is directly below the projectile (P). The target is in the ground plane at T, and the background return emanates from B. The azimuthal difference between designator-to-target line and projectile-to-target line is ϕ. The elevation of the projectile above the ground plane is θ. The reflecting object in the background is considered sharply defined.

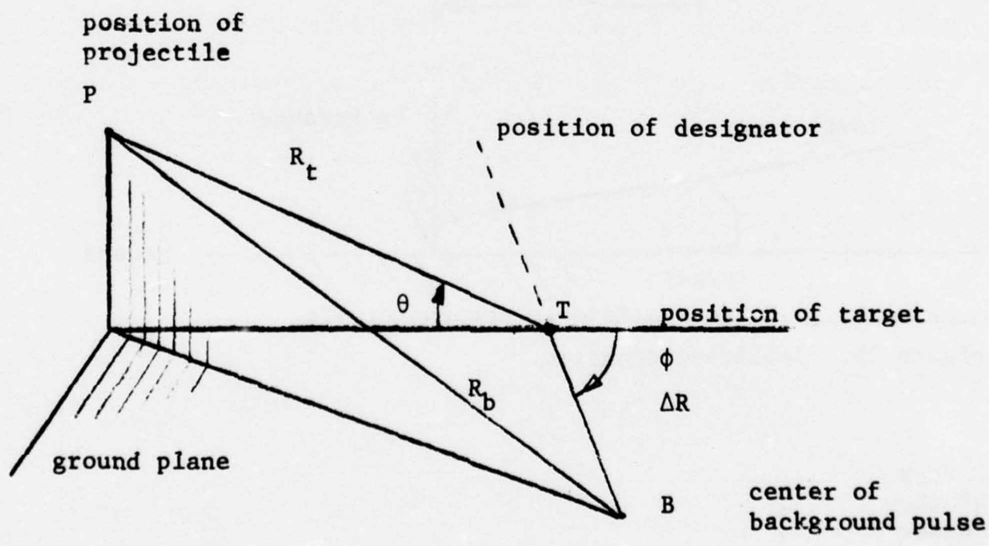


Figure 2a. Engagement Geometry.

DRSAR-SAM
SUBJECT: Proportion of Energy Spilled Over a Target During Tracking With a Laser Designator and Implications for Terminal Guidance

From the above geometry

$$R_b^2 = R_t^2 + \Delta R^2 + 2\ R_t\ \Delta R \cos\theta \cos\phi.$$

Then,

$$\gamma = [1 + (\Delta R/R_t)^2 + 2\ (\Delta R/R_t) \cos\theta \cos\phi]^{-1} \quad (11)$$

For example with these parameter values: R_t = 5000 ft, ΔR = 2000 ft, θ = 20 deg, ϕ = 25 deg, the value of γ = 0.543. For Copperhead these values are considered representative.

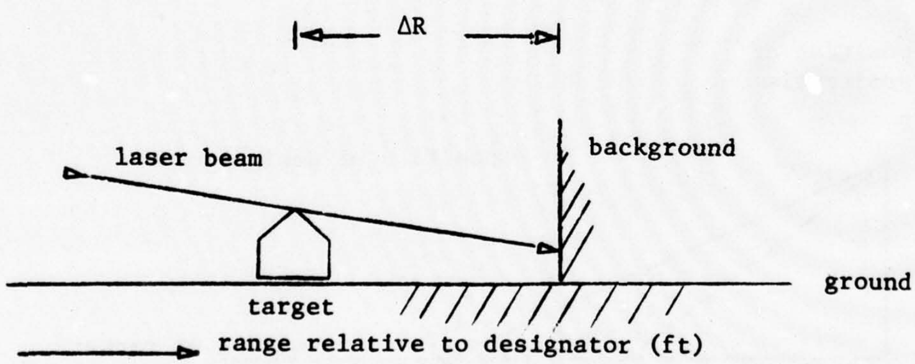


Figure 2b. Spillover Scenario.

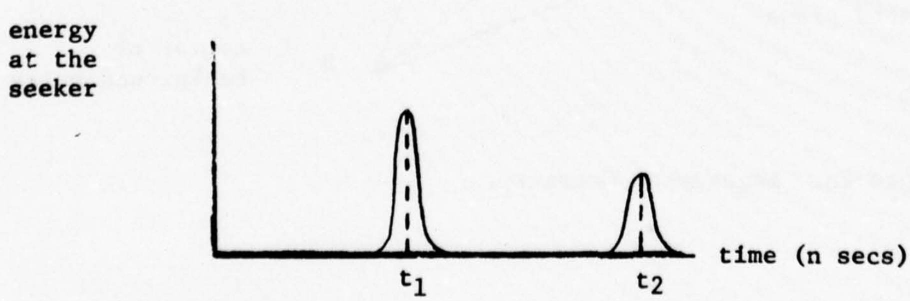


Figure 2c. Reflected Pulses at the Seeker.

10. The energy at the seeker due to reflection from the target is indicated at time t_1. The energy return from the background occurs at t_2. For small azimuthal difference between designator and seeker*, the time interval in nanosecs: t_2-t_1 is equal to the difference in path length in feet for the two paths--target to seeker and target to background to seeker. Exactly,

$$t_2-t_1 = \Delta R + R_b - R_t \tag{12a}$$

or

$$t_2-t_1 = \Delta R + R_t\,(\gamma^{-1/2} - 1). \tag{12b}$$

A useful approximation for our purpose is

$$t_2 - t_1 \text{ (n sec)} \cong 2\,\Delta R \text{ (ft)}. \tag{13}$$

In the example given above the exact value of this time interval is 3785 n sec compared to 4000 n sec for the approximation.

11. The target selection algorithm employed in Copperhead establishes a dynamic threshold illustrated in Figure 3.

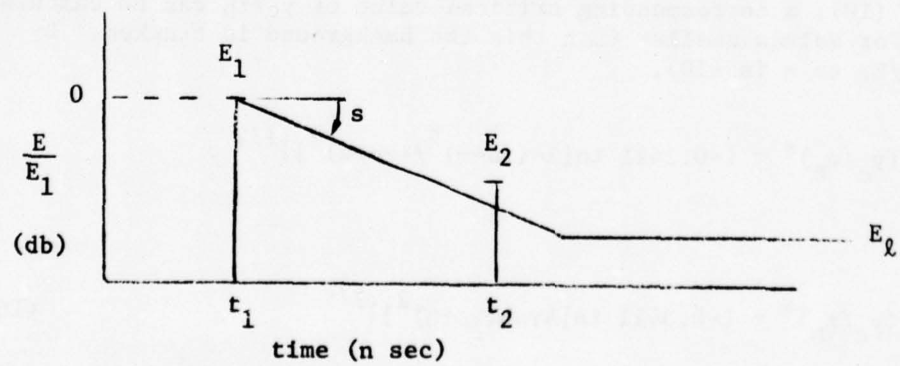


Figure 3. Plot of Energy Returns and Dynamic Threshold for Copperhead

---

* Background energy centroid mast remain in the seeker field of view for this analysis to hold.

Assuming that both t_1 and t_2 lie within admissible time gates (50 μ sec max for t_1), the occurance of a target pulse at t_1, whose maximum amplitude is represented as E_1, generates a linearly decreasing threshold E/E_1 on a logarithmic scale. The slope, s, of this threshold is presently 0.5 db/μ sec. This threshold decreases until a fixed relative minimum E_ℓ occurs. For example, E_ℓ is approximately 16 db below E_1. The selection logic is such that if $E_2 > E\ (t_2)$, the background is tracked. Otherwise, the target pulse is accepted and the target is tracked. The threshold value of E_2, E_2^*, at which the background is tracked is given by

$$10 \log_{10} (E_2^*/E_1) = - s\ (t_2 - t_1),\ E_2 > E_\ell\ . \qquad (14)$$

Approximately, from (13),

$$\eta \cong E_2^*/E_1 = \max\ (10^{-2\ s\ \Delta R},\ E_\ell/E_1)\ . \qquad (15)$$

Thus, with s and ΔR fixed (in a particular scenario), the threshold ratio E_2^*/E_1 is fixed. For example, with $s = 5\ 10^{-4}$ db/n sec and $\Delta R = 2000$ ft,

$$\eta = E_2^*/E_1 = 0.63\ .$$

12. In summary, the choice of parameters s and ΔR fixes the minimum ratio, E_b/E_t, of reflected energies from background and target, for which the background will be tracked, generating a significant background pulse. By equation (10), a corresponding critical value of y_c/r_b can be calculated, $(y_c/r_b)^*$. For values smaller than this the background is tracked. By equating E_b/E_t to η in (10),

$$(y_c/r_b)^* = \{-0.3411\ \ell n[1-(\gamma\rho-\eta)^2/(\gamma\rho+\eta)^2]\}^{1/2}\ .$$

or

$$(y_c/r_b)^* = \{-0.3411\ \ell n[4\gamma\rho\eta/(\gamma\rho+\eta)^2]\}^{1/2}\ . \qquad (16)$$

13. The beam radius in the far field is given approximately in terms of the beam divergence, β, and designation range, R:

$$r_b = \beta R/2 \quad \text{, with} \tag{17}$$

β in (milliradians) and R in (km) for r_b in (m).

For a constant beam radius, the nearest the beam centroid can approach the target edge without a significant background pulse is given by

$$y_c^* = (y_c/r_b)^* \ \beta R/2 \ . \tag{18}$$

14. <u>The Critical Designation Range</u>.

Using the notation in Ref 1c, let the distance from the center of aim* on the target to the top edge of the target be L. Then, the critical value (level) of the beam centroid relative to the center of aim* for significant background pulses is

$$u = L - y_c^* \ . \tag{19}$$

If the beam centroid makes an excursion greater than u, a significant background pulse will occur and be repeated as long as u is exceeded.

15. Following the practice of Ref 1c, the critical designation range is defined as that which produces a statistical expectation of three significant sequences of background pulses during a typical ten-second guidance period. The expected number of significant sequences is identical to the expected number of crossings of the level u in time T. From Ref 1c, the expected level crossings of a stationary stochastic process having second-order Butterworth dynamics and a one hertz corner frequency is

$$E(C) = 2T \exp\left(-u^2/2\sigma_t^2\right), \ ^{**} \tag{20}$$

---

* The center of aim is identified with the mean vertical coordinate of the spot motion occurring during tracking by the designator. Tracking jitter is treated as a stationary stochastic process.

** This result is derived in Annex 1.

where σ_t is the standard deviation of the tracking error. Over the designation ranges of interest σ_t is a linear function of range. Thus,

$$\sigma_t = s_t R \quad , \tag{21}$$

with s_t in (milliradians) and R in (km) to yield σ_t in (m).

From (20),

$$E(C) = 2T \exp[1-u^2/(2\, s_t^2\, R^2)]. \tag{22}$$

16. Applying the criterion for critical designation range R^*, we set E(C) = 3 and T = 10 sec. Then, solving for $u(R^*)/R^*$ in (22):

$$u(R^*)/R^* = s_t \sqrt{-2\, \ell n(3/20)} = 1.948\, s_t . \tag{23}$$

From (18, 19, 23), the critical designation range in (km) is

$$R^* = L/[1.948\, s_t + 0.5\, (y_c/r_b)^* \beta]. \tag{24}$$

The value of $(y_c/r_b)^*$ is given by (16).

17. <u>An Example</u>.

Take the computed value of $\eta = 0.63$ from the previous example as well as the following parameters: $\rho = 7$, $\gamma = 0.54$, $L = 0.8$ (m), $\beta = 0.15$ (millirad), and $s_t = 0.1$ (millirad). For these values $R^* = 3.45$ km. A comparable result given in Ref 1c for the same parameters but having a uniformly distributed beam energy produces R^* equal to 3.30 km, to three significant figures. Other parametric results of the above theory are given in Figures 4 thru 6 and Tables 1 thru 5.

18. Interpretation of Results.

Among the parameters examined several can be disposed of as being of slight importance in determining the critical designation range, R_{crit}. For this group the critical range is not very sensitive to changes in parameter values over the range of values examined (and expected operationally). For example, target-to-background range and seeker-to-target slant range are not particularly sensitive. Neither is the relative azimuth between the seeker-to-target and designator-to-target lines (seeker-designator azimuth). See Tables 1, 2, and 3. The background/target reflectance ratio, ρ, is somewhat more sensitive, producing a change of about 13% in R_{crit} while varying over the decade from 1 to 10. The reason for the greater sensitivity of ρ is illustrated in Figure 4. The critical position of the beam centroid with respect to the edge of the target is shown as a function of ρ. This critical position is seen to change from near zero to more than one-half a beam radius as ρ varies over the decade from 1 to 10. For most natural backgrounds and for Soviet target vehicles, the expected reflectance ratio is 7. This is the constant value of ρ chosen when other parameters are varied. In the same spirit, the seeker-designator azimuth was fixed at 25 deg when other factors were varied parametrically. The median attack azimuth obtained in operational combat simulations with Copperhead was 25 degrees. Similarly, the distance from target to background (ΔR) expected when significant laser spillover occurs during designation from well sited surface positions lies in the range from 1000 to 5000 ft, with 2000 ft being a typical value. Therefore, this constant value of ΔR was used for other parametric analyses.

19. One of the seeker parameters considered significant to target selection is the slope, s, of the seeker (target discrimination) threshold. The nominal value of s for Copperhead is 0.5 db/μ sec. However, changes in s by a factor of 2 (or 1/2) produce only slight changes in the critical position of the beam centroid (Table 5) and even smaller changes in the critical designation range (Table 3).

20. The most sensitive parameters affecting R_{crit} are beam divergence and tracking error. Of these parameters tracking error is the more significant, particularly for small values of beam divergence. See Table 4 and Figures 5 and 6. As long as beam divergence remains below about 0.2 milliradians the dominating effect of tracking accuracy is evident. To be sure, small improvements in R_{crit} can be obtained by having small (and fortunate) values of ρ or by making optimal adjustments in the seeker signal processing parameters or by further reduction in beam divergence, but the greatest improvement must depend

upon reduction of the standard deviation (SD) of spot motion. For example, halving the SD from 0.10 mr to 0.05 mr increases R_{crit} from 3.3 to 5.5 km, with a beam divergence of 0.2 mr and other parameters fixed at nominal. Since this increased designation range has some operational utility for Copperhead, the effort to reduce tracking error should be pursued.

George J. Schlenker

GEORGE J. SCHLENKER
Operations Research Analyst
Methodology Division
Systems Analysis Directorate

TABLE 1. EFFECTS OF TARGET-BACKGROUND DISTANCE AND REFLECTANCE RATIO ON THE CRITICAL DESIGNATION RANGE

Table entries are critical ranges in (km).

Target-to Background (ft)	Background/Target Reflectance Ratio				
	1	3	5	7	9
1000	4.069	3.832	3.711	3.639	3.590
2000	4.047	3.851	3.727	3.654	3.604
3000	4.036	3.860	3.736	3.662	3.611
4000	4.034	3.862	3.737	3.663	3.612
5000	4.040	3.857	3.733	3.659	3.608

Constant Parameters

seeker-target slant range	5000 ft
seeker-designator azimuth	0 deg
seeker elevation	20 deg
seeker threshold slope	0.5 db/μ sec
designator beam div	0.10 m r
designator tracking error SD	0.10 m r

TABLE 2. EFFECTS OF SEEKER-TO-DESIGNATOR AZIMUTH AND REFLECTANCE RATIO ON THE CRITICAL DESIGNATION RANGE

Table entries are critical ranges in (km).

Seeker-to-Designator Azimuth (deg)	Background/Target Reflectance Ratio				
	1	3	5	7	9
0	4.047	3.851	3.727	3.654	3.604
15	4.021	3.849	3.725	3.652	3.602
25	4.054	3.845	3.722	3.650	3.599
35	4.060	3.840	3.717	3.645	3.595
45	4.070	3.832	3.710	3.639	3.589

Constant Parameters

seeker-target slant range	5000 ft
target-background distance	2000 ft
seeker elevation	20 deg
seeker threshold slope	0.5 db/μ sec
designator beam divergence	0.10 mr
designator tracking error SD	0.10 mr

TABLE 3. EFFECTS OF SEEKER-TO-TARGET SLANT RANGE AND SEEKER THRESHOLD SLOPE ON THE CRITICAL DESIGNATION RANGE

Table entries are critical ranges in (km).

Seeker Azimuth (deg)	Seeker Slant Range (ft)	Seeker (Target Discrimination) Threshold Slope (db/μ sec)		
		0.25	0.50	1.00
25	5000	3.696	3.650	3.565
0	5000	3.702	3.654	3.566
0	2000	3.873	3.815	3.708
0	1000	4.106	4.037	3.908

Constant Parameters

target-background distance	2000 ft
seeker elevation	20 deg
background/target reflectance	7
designator beam divergence	0.10 mr
designator tracking error SD	0.10 mr

TABLE 4. EFFECTS OF DESIGNATOR BEAM DIVERGENCE AND TRACKING ACCURACY ON THE CRITICAL DESIGNATION RANGE

Table entries are critical ranges in (km).

Beam Divergence (milliradians)	Tracking Error Standard Deviation (milliradians)				
	0.05	0.10	0.15	0.20	0.25
Background/Target Reflectance = 3					
0.10	7.230	3.845	2.619	1.986	1.599
0.15	6.821	3.726	2.563	1.954	1.578
0.20	6.456	3.615	2.510	1.923	1.558
0.25	6.128	3.510	2.459	1.892	1.538
0.30	5.832	3.410	2.410	1.863	1.519
Background/Target Reflectance = 7					
0.10	6.568	3.650	2.527	1.932	1.564
0.15	5.969	3.457	2.433	1.877	1.528
0.20	5.471	3.284	2.346	1.825	1.493
0.25	5.049	3.127	2.265	1.775	1.460
0.30	4.688	2.985	2.189	1.728	1.428

Constant Parameters

seeker-target slant range	5000 ft
target-background distance	2000 ft
seeker-designator azimuth	25 deg
seeker elevation	20 deg
seeker threshold slope	0.5 db/μ sec

TABLE 5. CRITICAL POSITION OF BEAM CENTROID $(y_c/r_b)^*$ AS A FUNCTION OF REFLECTANCE RATIO (ρ) AND SEEKER THRESHOLD SLOPE (s)

Reflectance Ratio, ρ	Seeker Threshold Slope, s (db/μ sec) 0.25	0.50	1.00
1	.0626	.0311	.0319
2	.1391	.1700	.2313
3	.2541	.2840	.3428
4	.3330	.3620	.4186
5	.3924	.4204	.4753
6	.4395	.4669	.5201
7	.4784	.5051	.5571
8	.5114	.5375	.5883
9	.5398	.5654	.6153
10	.5648	.5900	.6390

Constant Parameters

seeker-target slant range	5000 ft
target-background distance	1000 ft
seeker-designator azimuth	25 deg
seeker elevation	20 deg

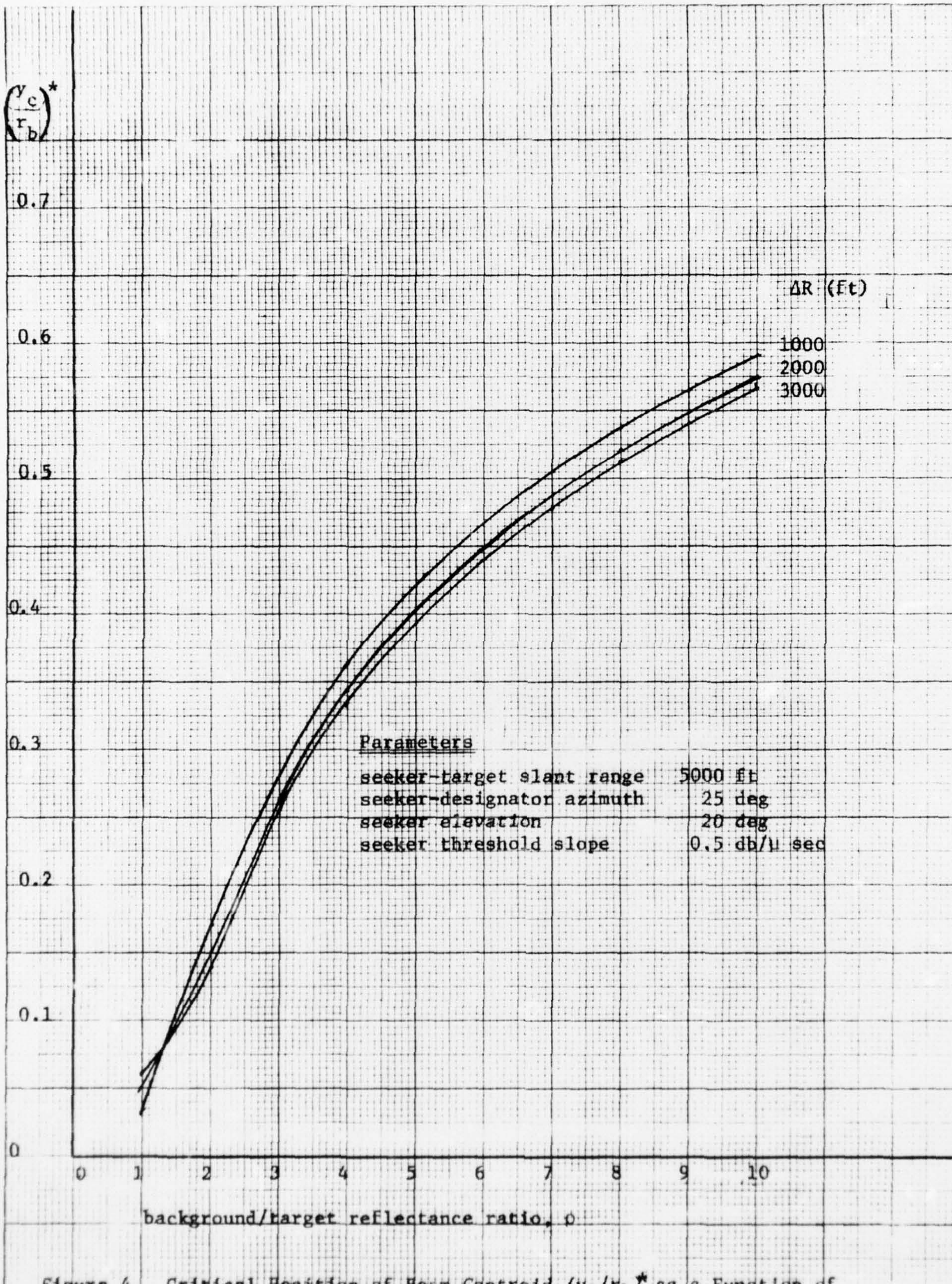


Figure 4. Critical Position of Beam Centroid $(y_c/r_b)^*$ as a Function of Reflectance Ratio (ρ) and Target-Background Distance (ΔR)

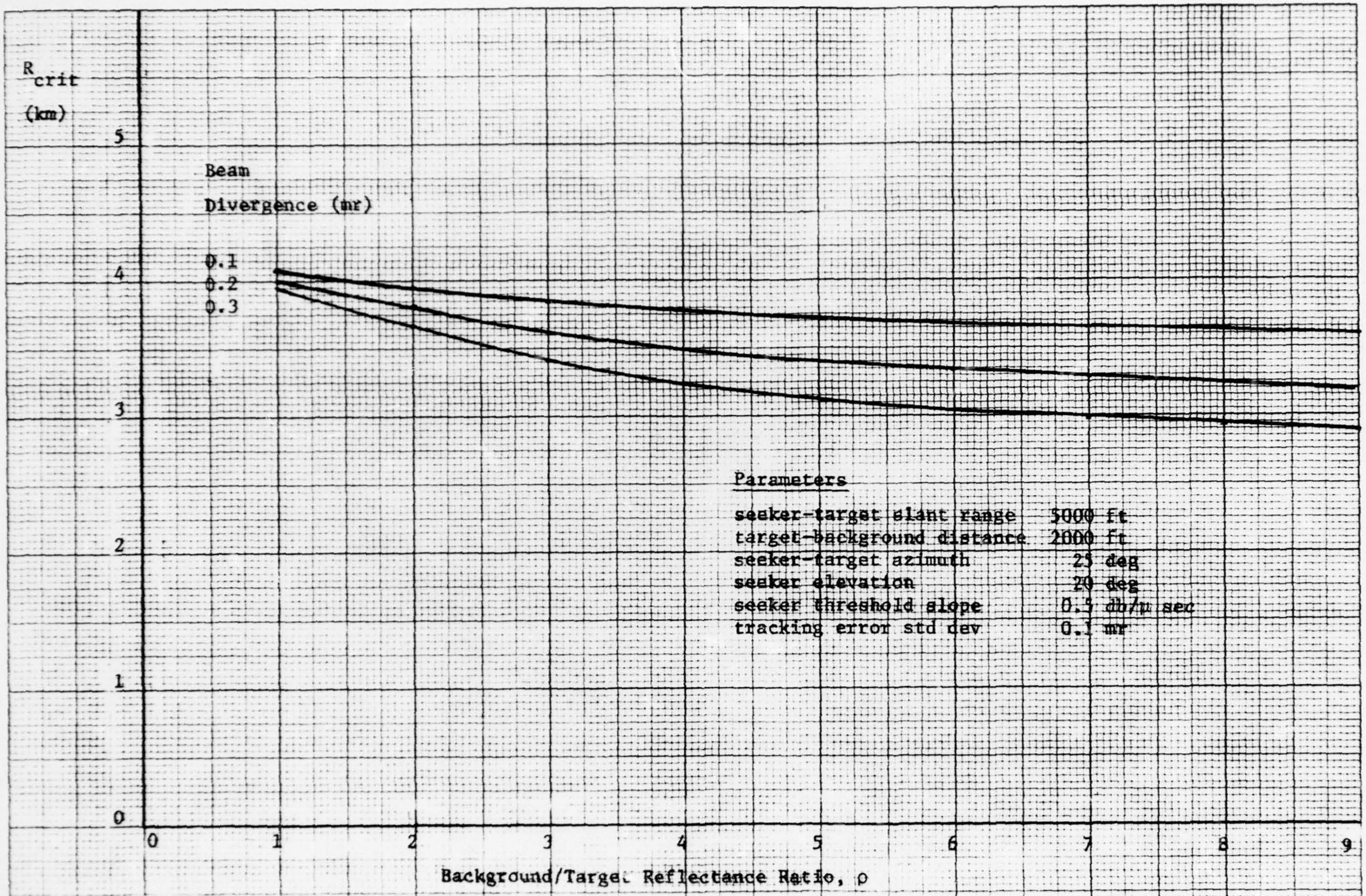


Figure 5. Critical Designation Range As a Function of Background/Target Reflectance Ratio for Several Values of Beam Divergence

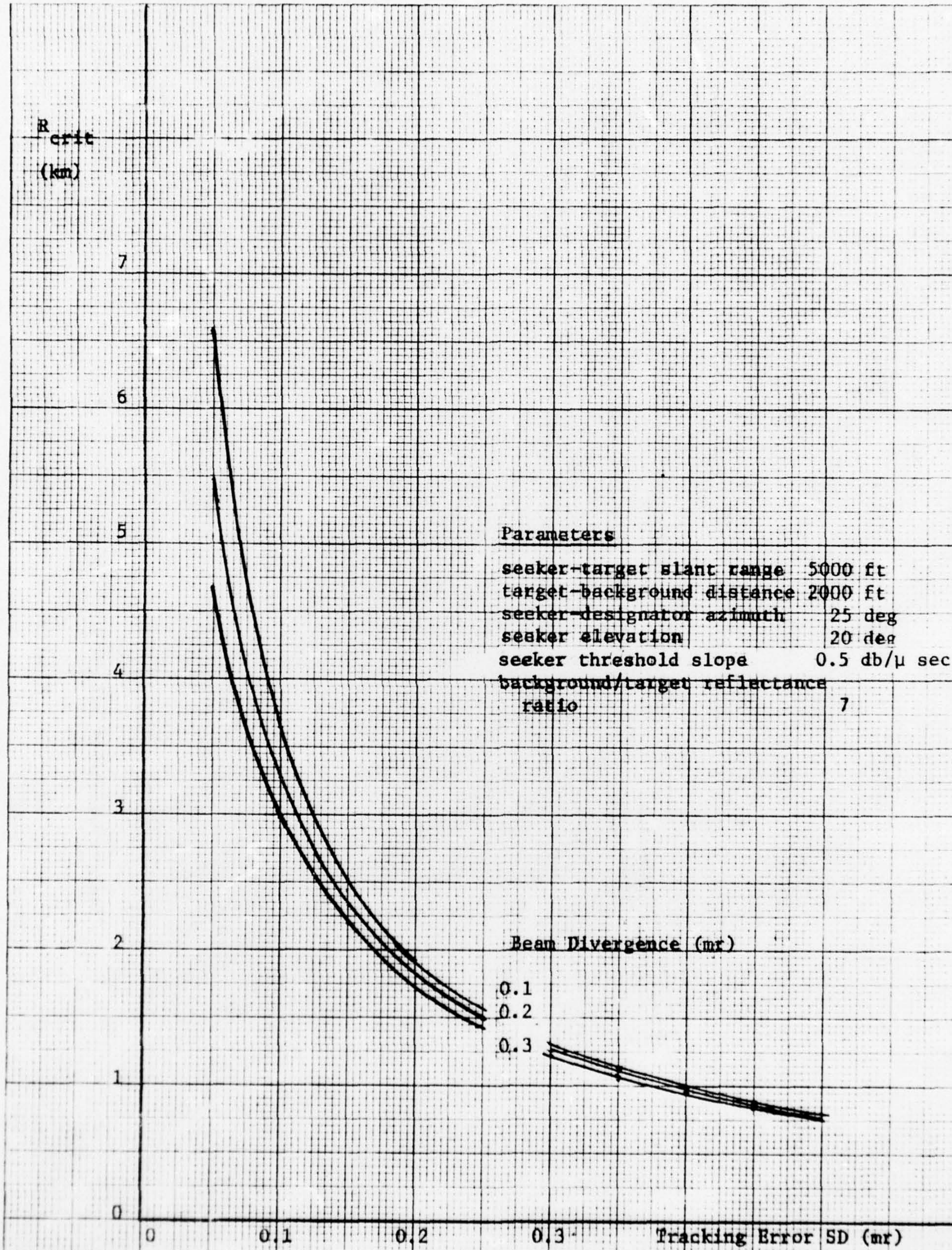


Figure 6. Critical Designation Range As a Function of Tracking Error With Beam Divergence as a Parameter

ANNEX 1

A Result on Level-Crossings for Second-Order Stochastic Processes

From p. 437, "Stochastic Point Processes: Statistical Analysis, Theory and Applications," Lewis, 1972:*

The mean number of crossings of a level u by a stationary (zero mean) normal stochastic process $\xi(t)$ in an interval $0 \leq t \leq T$

$$E(C) = \frac{T}{\pi} \left(\frac{\lambda_2}{\lambda_o}\right)^{\frac{1}{2}} \exp(-u^2/2\lambda_o) \quad , \tag{1a}$$

where, if $r(\tau)$ denotes the covariance function of $\xi(t)$,

$$\lambda_o = r(0) = \text{var } \xi(t) \tag{1b}$$

and $\lambda_2 = -r''(0)$, the second derivative of r at the origin. Note that λ_2 is also the second spectral moment

$$\lambda_2 = \int_o^\infty \lambda^2 \, d\, F(\lambda) \tag{1c}$$

if F denotes the spectral function for $\xi(t)$.

<u>An Example</u>

The transfer function for a second-order Butterworth stochastic system is

$$H_x(s) = \frac{K\, \omega_a^2}{s^2 + \sqrt{2}\, \omega_a\, s + \omega_a^2} \tag{2}$$

where K is the amplitude constant and

$$\omega_a = 2\, \pi\, \nu_a$$

*Lewis, P. A. <u>Stochastic Point Processes: Statistical Analysis, Theory and Applications</u>, Wiley Interscience, New York, c. 1972.

with ν_a the analog corner frequency in hertz.

The transfer function produces the spectral density as follows:

$$\Gamma_{xx}(\omega) = \left|H_x(j\omega)\right|^2$$

$$= \frac{K^2 \omega_a^4}{[(j\omega)^2 + \sqrt{2}\, j\, \omega_a\, \omega + \omega_a^2]} \; \frac{1}{[-\omega^2 - \sqrt{2}\, j\, \omega_a\, \omega + \omega_a^2]}$$

$$= \frac{K^2 \omega_a^4}{(\omega_a^2 - \omega^2)^2 + 2\, \omega_a^2\, \omega^2}$$

$$= \frac{K^2 \omega_a^4}{\omega_a^4 + \omega^4}$$

$$\Gamma_{xx}(\omega) = \frac{K^2}{1 + (\omega/\omega_a)^4} \tag{3}$$

$$\Gamma'_{xx}(f) = \frac{K^2}{1 + f^4} \tag{4}$$

where

$$f = \omega/\omega_a$$

If we require that the process have unity variance,

$$\int_0^\infty \Gamma_{xx}(\omega)\, d\omega = 1 \tag{5}$$

and

$$\int_0^\infty \frac{K^2\, d\omega}{1 + (\omega/\omega_a)^4} = 1$$

$$\omega_a K^2 \int_0^\infty \frac{d(\omega/\omega_a)}{1 + (\omega/\omega_a)^4} = 1$$

$$K^2 = \omega_a^{-1} \Big/ \int_0^\infty \frac{df}{1 + f^4} \quad . \tag{6}$$

But with

$$\int_0^\infty \frac{x^{p-1} dx}{1 + x^q} = \frac{\pi}{q \sin(\frac{p\pi}{q})} \quad , \tag{7}$$

$$K^2 = \omega_a^{-1} \Big/ \left(\frac{\pi\sqrt{2}}{4}\right)$$

$$K^2 = \frac{4}{\omega_a \pi \sqrt{2}} \quad . \tag{8}$$

The second spectral moment for a second-order Butterworth noise process is

$$\lambda_2 = \int_0^\infty \omega^2 \Gamma_{xx}(\omega) \, d\omega$$

$$= K^2 \omega_a^3 \int_0^\infty \frac{f^2 \, df}{1 + f^4}$$

$$\lambda_2 = \frac{4 \omega_a^2}{\pi \sqrt{2}} \int_0^\infty \frac{f^2 \, df}{1 + f^4} \quad . \tag{9}$$

Then, with (7)

$$\lambda_2 = \frac{4 \omega_a^2}{\pi \sqrt{2}} \frac{\pi}{4 \sin(\frac{3\pi}{4})} = \omega_a^2 \quad . \tag{10}$$

From (1), the expected number of crossings of level u in time T for a second-order Butterworth process with variance σ^2 assumes the simple form

$$E(C) = \frac{T\ \omega_a}{\pi} \exp(-u^2/2\sigma^2)$$

or

$$E(C) = 2\ T\ \nu_a \exp(-u^2/2\sigma^2) \qquad (11)$$

where ν_a is the corner frequency.